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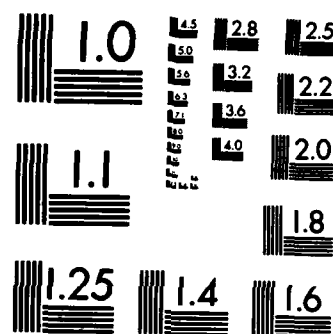
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SIMULATION METHODOLOGY

by

Donald L. Iglehart

FINAL REPORT

December 1983

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for the

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FINAL REPORT ON CONTRACT N00014-76-C-0578

This final report on contract N00014-76-C-0578 with Stanford University, entitled **Simulation Methodology**, covers the period January 1, 1976 to September 30, 1983. This contract partially supported the research of the Principal Investigator and Project Director, Dr. Donald L. Iglehart, as well as seven Ph.D. students in the Department of Operations Research. The Ph.D. dissertations of these students all appeared under this contract.

A. Summary of Significant Accomplishments

→ This Bibliography Lists

During the period January 1, 1976 to September 30, 1983 thirty-one technical reports were issued. The principal topics covered in this research were condition limit theorems for Markov chains, variance reduction techniques for Markov chains, simulation of response times in networks of queues, simulation of generalized semi-Markov processes and general state space Markov chains, asymptotic theory for nonparameteric confidence intervals, an autoregressive method for simulation output analysis, simulation of non-Markovian systems, and simulation output analysis for local area computer networks. Toward the end of this period research began on the development of algorithms to optimize systems parameters for simulation. An approach using smoothing splines has been developed. This work was not completed and written up prior to the expiration of the contract. A report on this work is still planned.

The work accomplished under this contract has significantly enhanced the theoretical foundations for simulation output analysis. Major improvements were made to the regenerative method for generating confidence intervals for steady state system performance characteristics. A new autoregressive method for handling this problem was also developed. In addition, variance reduction techniques designed to make our simulations more efficient were established. Substantial progress was made in understanding how to analyze output from non-Markovian systems. This area seems particularly important for future developments. Our research will continue in this direction.



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B. Technical Reports Issued on Contract N00014-76-C-0578

<u>Author</u>	<u>Title</u>	<u>Report No.</u>	<u>Date of Report</u>
38. Peichuen Kao	Conditioned Limit Theorems in Queueing Theory ( <u>Journal of Applied Probability</u> 15 (1978), 280-291)	38	July 1976
39. Richard Durrett	Conditioned Limit Theorems for Some Null Recurrent Markov Processes ( <u>Annals of Probability</u> 6 (1978), 798-828)	39	August 1976
40. Douglas P. Kennedy	On the Time to First Overflow in Dams with Inputs Forming a Markov Chain ( <u>Journal of Applied Probability</u> 15 (1978), 171-178)	40	August 1976
41. Philip Heidelberger	Variance Reduction Techniques for Simulating Markov Chains (published in <u>Proc. of 1977 Winter Simulation Conference</u> )	41	September 1977
42. Philip Heidelberger	Variance Reduction Techniques for the Simulation of Markov Processes, I: Multiple Estimates (submitted for publication)	42	October 1977
43. Donald L. Iglehart	Regenerative Simulation for Extreme Values	43	October 1977
44. Philip Heidelberger	Variance Reduction Techniques for the Simulation of Markov Processes, II: Matrix Iterative Methods (submitted for publication)	44	January 1978
45. Philip Heidelberger	Variance Reduction Techniques for the Simulation of Markov Processes, III: Increasing the Frequency of Regenerations (submitted for publication)	45	January 1978
46. Donald L. Iglehart Peter A.W. Lewis	Regenerative Simulation with Internal Controls ( <u>Journal of Association of Computing Machinery</u> 26 (1979), 271-282)	46	February 1978

<u>Author</u>	<u>Title</u>	<u>Report No.</u>	<u>Date of Report</u>	
47. Philip Heidelberger Donald L. Iglehart	Comparing Stochastic Systems Using Regenerative Simulation with Common Random Numbers ( <u>Advances in Applied Probability</u> <u>11</u> (1979), 804-819)	47	May	1978
48. Donald L. Iglehart Gerald S. Shedler	Regenerative Simulation of Response Times in Networks of Queues, II: Multiple Job Types ( <u>Acta Informatica</u> <u>12</u> (1979), 159-175)	48	June	1978
49. Donald L. Iglehart Gerald S. Shedler	Simulation Methods for Response Times in Networks of Queues ( <u>Proceeding of 1979 Winter Simulation Conference</u> , I, 221-232)	49	August	1979
50. Lawrence D. Fossett	Simulating Generalized Semi-Markov Processes (Ph.D. dissertation)	50	September	1979
51. Donald L. Iglehart Gerald S. Shedler	Regenerative Simulation of Response Times in Networks of Queues: Statistical Efficiency (published in <u>Acta Informatica</u> <u>15</u> (1981), 347-363)	51	September	1979
52. Donald L. Iglehart Gerald S. Shedler	Regenerative Simulation of Response Times in Networks of Queues ( <u>Lecture Notes in Control and Information Sciences</u> series, Vol. 26, Springer-Verlag)	52	November	1979
53. Peter W. Glynn	An Approach to Regenerative Simulation on a General State Space	53	July	1980
54. Peter W. Glynn Donald L. Iglehart	Simulation Output Analysis for General State Space Markov Chains (published in <u>Applied Probability - Computer Science: The Interface I</u> (1982), 71-88, Birkhäuser, Boston)	54	February	1981
55. Peter W. Glynn	On the Markov Property of the GI/G/ $\infty$ (published in <u>Advances in Applied Probability</u> <u>14</u> (1982), 191-194)	55	May	1981

	<u>Author</u>	<u>Title</u>	<u>Report No.</u>	<u>Date of Report</u>	
56.	Peter W. Glynn	On Variance Formulas for the Sample Mean in Finite State Markov Processes (to appear in <u>J. Stat. and Simulation</u> )	56	July	1981
57.	Donald L. Iglehart Gerald S. Shedler	Simulation for Passage Times in Closed, Multiclass Networks of Queues with General Service Times (submitted for publication)	57	July	1981
58.	Donald L. Iglehart Gerald S. Shedler	Statistical Efficiency of Regenerative Simulation Methods for Networks of Queues ( <u>Advances in Applied Probability</u> <u>15</u> (1983), 183-197)	58	May	1982
59.	Peter W. Glynn	Coverage Error for Confidence Intervals Arising in Simulation Output Analysis (published in <u>Proc. of 1982 Winter Simulation Conference</u> <u>12</u> (1982), 369-375)	59	June	1982
60.	Peter W. Glynn	Some New Results in Regenerative Process Theory (Ph.D. dissertation)	60	July	1982
61.	Peter W. Glynn	Regenerative Aspects of the Steady/State Simulation Problem for Markov Chains (Ph.D. dissertation)	61	July	1982
62.	Peter W. Glynn	Regenerative Simulation of Harris Recurrent Markov Chains	62	July	1982
63.	Peter W. Glynn	Asymptotic Theory for Non-parametric Confidence Intervals (Ph.D. dissertation)	63	July	1982
64.	Donald L. Iglehart Mark L. Stone	Regenerative Simulation for Estimating Extreme Values (to appear in <u>Operations Research</u> , Dec. 1983)	64	July	1982
65.	Yung-Li Lily Jow	An Autoregressive Method for Simulation Output Analysis (Ph.D. dissertation)	65	December	1982

	<u>Author</u>	<u>Title</u>	<u>Report No.</u>	<u>Date of Report</u>	
66.	Donald L. Iglehart Gerald S. Shedler	Simulation of non-Markovian Systems, ( <u>IBM Journal of Research and Development</u> , p. 477-479)	66	June	1983
67.	Donald L. Iglehart Gerald S. Shedler	Simulation Output Analysis for Local Area Computer Networks (Submitted to <u>Acta Informatica</u> .)	67	September	1983
68.	Donald L. Iglehart Gerald S. Shedler	Simulation for Passage Times in Non-Markovian Networks of Queues (to appear in the <u>Proceedings of the Stochastic Programming Conference</u> , Lake Garda)	68	September	1983



C. ACKNOWLEDGEMENTS

Dr. Iglehart wishes to express his gratitude to the Office of Naval Research for funding this research. This support has enabled us to make significant contributions to simulation methodology as well as to train young Ph.D. students in the area.

*D. L. Iglehart*

Donald L. Iglehart  
December 28, 1983

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